# THE INPUT OF TERRESTRIAL INSECTS AND SPIDERS TO THE NUTRIENT CYCLE OF A "WOODLAND POND"[1]

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ABSTRACT: Terrestrial insects (and spiders) falling upon the 34.56 $m^2$ surface of a swimming pool were collected during 13 1-hour periods. The numbers of insects/$m^2$/hour averaged 2.44 (range 0.67-5.24). Dry weight (mg/$m^2$/hour) averaged 1.3 (range 0.67-3.86). Diptera were by far the most abundant group, followed by ants and Hemiptera-Homoptera. The results are compared with those of previous studies, and it is concluded that the energy input of terrestrial insects may be significant and is sometimes of major importance.

A typical pond receives energy not only from production within the pond (autochthonous) but also from sources outside the pond (allochthonous). The latter include particulate organic matter from the atmosphere and inflow, and dissolved organic matter in rain and inflow. The particulate organic matter includes derivatives from vegetation such as leaves, flowers, fruits, and terrestrial insects that fly or fall into the pond. My "woodland pond" is actually an inground swimming pool in my back yard in a residential section of Montgomery County, Maryland, in the suburbs of Washington, D.C. The pool is kidney-shaped, has a maximum depth of 5 ft., and a surface area of 34.56 $m^2$ (372 $ft^2$) (Fig. 1). A concrete patio surrounds the pool, which is bounded on the east side by a house, on the north side by a stand of bamboo, and on the south side by a small lawn and a flowering crab apple (*Pyrus* sp.). On the west side is a heavily wooded slope extending uphill about 12 m (40 ft). The trees nearest to the pool are a pin oak (*Quercus palustris*), a hackberry (*Celtis occidentalis*), a Chinese chestnut (*Castanea mollissima*), a mulberry (*Morus* sp.), and a silver maple (*Acer saccharinum*). Farther up the slope are several dwarf apple trees (*Pyrus malus*), a redbud (*Cercis canadensis*), a catalpa (*Catalpa bignonioides*), a Carpathian walnut (*Juglans regia*), a black locust (*Robinia pseudoacacia*), a chestnut oak (*Quercus montana*), and several staghorn sumacs (*Rhus typhina*). The undergrowth is dominated by ferns, periwinkle (*Vinca minor*), multiflora rose (*Rosa multiflora*), and rose of sharon (*Hibiscus syriacus*). The overall effect is that of a wild woodland rather than of the usual suburban backyard; hence I believe comparing my swimming pool to a woodland pond as a "trap" for terrestrial insects is a reasonable rather than an artificial exercise.

Among the accessories that came with the pool when it was installed

[1]Received February 16, 1988. Accepted April 25, 1988.

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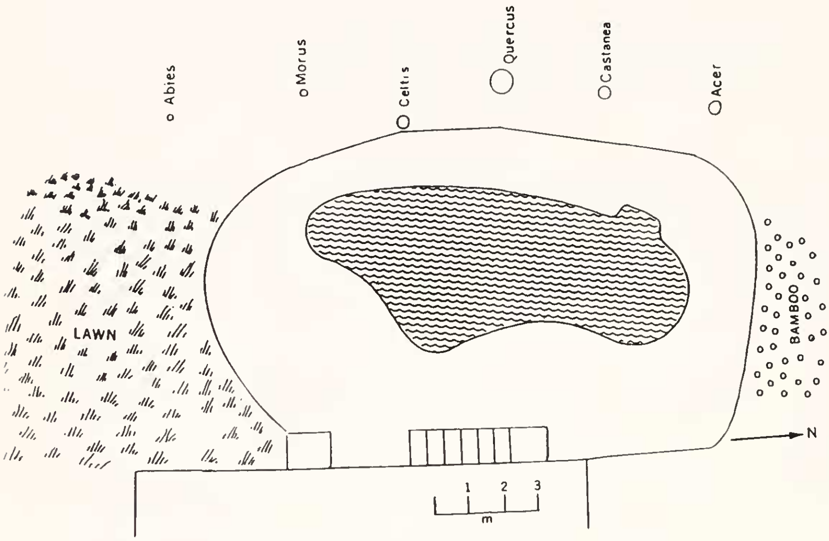


Figure 1. The swimming pool (wavy pattern) and its environs.

was a long-handled net to help keep the pool clean by removing debris from the pool surface. After a period of using the net, the composition of the debris was apparent. It consisted mainly of two components: (1) leaves, flowers, and seeds from nearby trees, (2) terrestrial insects and a few spiders. The quantity of insects was surprising to me, but I assumed that such an obvious source of organic material and energy to the aquatic community must surely be well documented and quantified in the literature on pond energetics. Indeed, I have been advised by an anonymous ecologist that "The fact that terrestrial insect contributions to the energy cycle in lentic waters are sometimes significant is well documented in the literature."

Despite my assumption and statements such as the above, I have been able to find only a few evaluations of this insect component in the limnological literature, and even fewer measurements based on quantitative sampling from a pond surface (see "Discussion" section). The opportunity to make a small contribution to this deficit in our knowledge prompted the present study.

The scope of this study is intentionally limited. My objective is to call attention to an energy source that has been largely overlooked, and to give some measurements of its magnitude in a particular habitat. My samples give only a slight indication of the variation with time of day and season of the year, and such variation needs to be assessed. I hope that my preliminary results will induce more detailed studies on terrestrial insects as an energy source to aquatic habitats.

## METHODS AND MATERIALS

Collections were made of all the insects and spiders that fell into the pool during periods of 1 hr (44 min in 1 collection). The arthropods were collected either with a fine-meshed net or dipped out with a small dish or pan. Immediately before the collection period all insects were carefully removed from the pool surface. Collections were made by reaching in from the sides of the pool or by wading in the pool. In the latter case care was taken not to stir up dead insects from the bottom of the pool. At the end of the collection period the specimens were preserved in 70% ethanol. Thirteen collections were made during the spring and summer in 1982 and 1983.

The sampling methods, while simple and unsophisticated, were highly effective, since individual insects as small as 0.6 mm in length (tiny Hymenoptera) were easily seen and collected. I estimate that from 95-99% of the insects falling into the pool were collected.

Insects were enumerated to order, except that Homoptera and Hemiptera were combined as they were by Sage (1982), and ants were separated from other Hymenoptera.

Each specimen was measured in a dissecting microscope equipped with a camera lucida, and dry weights were calculated using regression statistics given by Sage (1982) for converting body lengths into weights according to the formula $\ln Y = a + bX - b^1X^2$, where Y = weight, X = body length, and a,b, and $b^1$ are regression coefficients determined by Sage. Calories were calculated using Golley's (1961) conversion factor for the locust *Schistocerca*, 1 g dry weight = 5363 gcal.

## RESULTS

The results are summarized in Figs. 2 and 3 and Tables 1-3. The hour's collections averaged 84, with a range of 23-181 insects. The number of insects collected/$m^2$ averaged 2.44, with a range of 0.67-5.24. In dry weight this averaged 1.39 mg/$m^2$, with a range of 0.27-3.86. There was no obvious relation between the numbers or mass of insects and the time of day or season, but the temporal scope of the collecting was rather limited because of the preference of the collector for carrying out field work under pleasant conditions.

Diptera were by far the most abundant group in the samples, ranking first in 9 of the 13 samples and averaging almost 44% of all the insects collected. Of the 13 samples, Diptera ranked first in abundance in 9, second in 3, and third in 1. In total dry weight the Diptera ranked first in 10 samples and third in 3 samples.

Ants were second in abundance. They ranked first numerically in 3 samples, second in 7 samples, and third in 3 samples. In dry weight they ranked first in 2 samples, second in 5, third in 3, fourth in 1, and fifth in 2 samples.

Besides the flies and ants, the Hemiptera-Homoptera was the only group that occurred in all 13 samples. Numerically they ranked first in 1 sample, third in 9 samples, and fourth in 3 samples. In dry weight they ranked third in 2 samples, fourth in 7 samples, sixth in 3 samples, and seventh in one sample. A noteworthy member of this group was the hackberry psyllid, a locally abundant species as shown by the presence of numerous galls on virtually every leaf of the hackberry tree.

Collembola occurred in 8 of the 13 samples, numerically ranking fourth 3 times, fifth twice, sixth twice, and seventh once. In dry weight they ranked second in 1 sample, fourth in 1, fifth in 3, sixth, seventh, and eighth each in 1 sample.

None of the other groups contributed important amounts in numbers or weights. Spiders occurred in 8 samples, but were small and few in number.

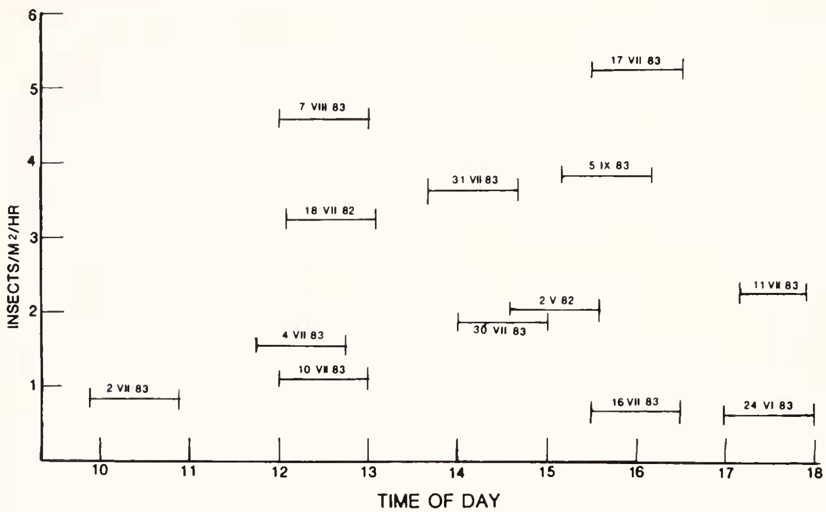


Figure 2. Numbers of insects and spiders collected from pool surface, with dates and times of collection.

## DISCUSSION

The input of terrestrial insects to a stream in southern England was measured by Mason and Macdonald (1982). Their collections were made with 20 buckets, 30 cm in diameter, suspended from posts at a height of 1 m along the edge of the stream. The buckets contained water to a depth of 5 cm, plus formalin. Sampling was carried out for 14 2-week periods for a total of 28 weeks. Their results are given for the entire 28 weeks; I have calculated the numbers/hr by dividing by 1960, assuming 10 hrs of collecting per day. The numbers of insects collected per hr ranged from 0.64-25.45, compared to 0.67-5.24 for my swimming pool, and the dry weights (mg/m$^2$) ranged from 3.79-48.53, compared to 0.27-3.86 for the pool. Thus Mason and Macdonald's results are somewhat higher than mine, but comparable to them.

In their analysis of the energy flow in a small (about 1 ha.) north-central Texas pond, Childress *et al.* (1981) found the input of terrestrial insects to be 1.28X10$^6$ kcal/yr. Dividing by 365 (days in a year), 10 (hours in a day), and 10,000 (m$^2$ in a ha.) gives 0.035 kcal/m$^2$/hr or 35.07 gcal/m$^2$/hr, somewhat higher than my figure for the pool, 1.44-20.70 (mean 7.43)

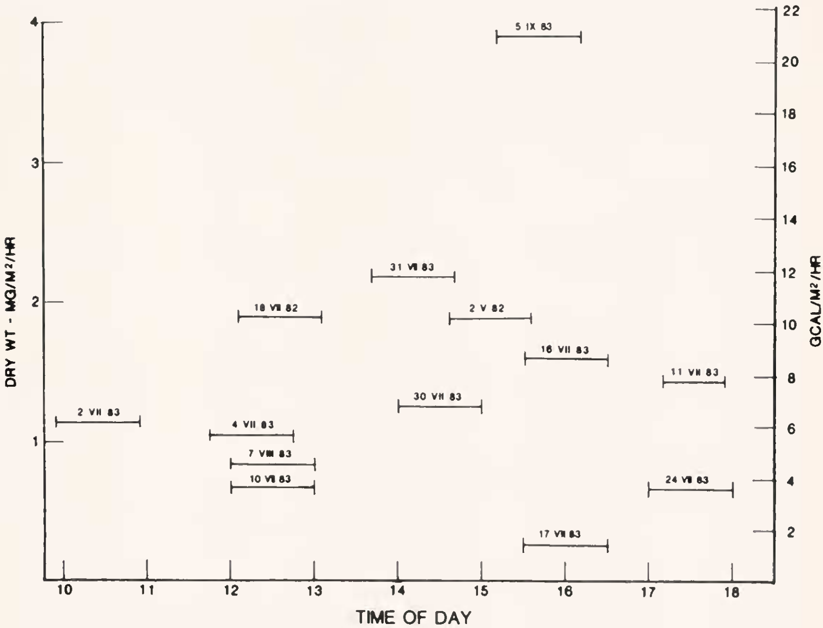


Figure 3. Dry weights and caloric values of insects and spiders collected from pool surface, with dates and times of collection.

gcal/m$^2$/hr. Childress *et al.* did not state how they arrived at their figure. Odum (1971), citing unpublished data from Welch (1967) for a Georgia pond managed for sport fishing, gave an input of 3 kcal/m$^2$/yr for terrestrial insects. This is the equivalent of 0.82 gcal/m$^2$/hr, which is lower than but close to the input to the pool. Odum did not reveal how Welch's input was determined. The caloric values for Mason and Macdonald's (1982) insect collections ranged from 20.33-260.27 gcal/m$^2$/hr.

How significant is the contribution of terrestrial insects to the food web of ponds and streams? Mason and Macdonald (1982) concluded that "The input of terrestrial invertebrates may then be equivalent to, or possibly greater than, the within-stream production of benthic invertebrates". In the Texas pond of Childress *et al.* (1981), terrestrial insects contributed 83.66% of the caloric energy to tertiary consumers (fish). But in a Canadian pond, where airborne particulate matter was collected in anchored plastic pools, 120 cm in diameter, containing rainwater, it contributed only 0.22% of the yearly organic carbon budget, 35 kg C/yr (Carpenter *et al.*, 1983). Probably a large part of this airborne matter consisted of insects, but the authors did not separate them from other particulate matter.

These studies and the present "woodland pond" measurements demonstrate that the contribution of terrestrial insects to the energy cycle of lentic

Table 1. Insects and spiders collected from surface of Bowman swimming pool (surface area 34.56 m$^2$) during 13 1-hr periods in 1982 and 1983.

| Date | Time | No./m$^2$/hr | Dry wt mg/m$^2$/hr | gcal/m$^2$/hr |
|---|---|---|---|---|
| 1982 | | | | |
| 2 May | 1435-1535 | 2.05 | 1.49 | 7.99 |
| 18 July | 1205-1305 | 3.24 | 1.49 | 8.00 |
| 1983 | | | | |
| 2 July | 0954-1054 | 0.81 | 1.15 | 6.17 |
| 4 July | 1145-1245 | 1.53 | 1.03 | 5.52 |
| 10 July | 1200-1300 | 1.10 | 0.68 | 3.65 |
| 11 July | 1710-1754 | 2.55 | 1.45 | 7.78 |
| 16 July | 1530-1630 | 0.69 | 1.61 | 8.63 |
| 17 July | 1530-1630 | 5.24 | 0.27 | 1.45 |
| 24 July | 1700-1800 | 0.67 | 0.67 | 3.59 |
| 30 July | 1400-1500 | 1.88 | 1.26 | 6.76 |
| 31 July | 1340-1440 | 3.62 | 2.20 | 11.80 |
| 7 Aug | 1200-1300 | 4.60 | 0.85 | 4.56 |
| 5 Sept | 1510-1610 | 3.70 | 3.86 | 20.70 |
| | | Mean 2.44 | 1.39 | 7.43 |

Table 2. Percentages of different insect taxa in 13 1-hr samples from surface of Bowman swimming pool.

| | Total Number | Diptera | Formicidae | Other Hymenoptera | Hemiptera-Homoptera | Coleoptera | Collembola | Orthoptera | Thysanura | Isoptera | Lepidoptera | Dermaptera | Protura | larvae | unidentified | Arachnida |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1982 | | | | | | | | | | | | | | | | |
| 2 May | 71 | 16.33 | 19.72 | 2.82 | 39.44 | 4.23 | – | – | – | 1.41 | – | – | – | – | – | – |
| 18 July | 112 | 83.04 | 8.04 | 0.89 | 5.35 | – | – | – | – | – | – | – | – | – | – | 2.68 |
| 1983 | | | | | | | | | | | | | | | | |
| 2 July | 28 | 21.42 | 50.00 | – | 14.29 | – | 3.57 | – | – | – | – | 3.57 | – | 7.14 | – | – |
| 4 July | 53 | 39.62 | 24.53 | 3.77 | 13.21 | – | 9.43 | 1.89 | – | – | – | – | – | 5.66 | 1.89 | – |
| 10 July | 38 | 47.36 | 18.42 | 5.26 | 10.53 | 5.26 | – | – | – | – | – | – | – | – | 10.53 | 2.63 |
| 11 July | | 88 | 38.64 | 22.73 | 1.14 | 10.61 | 3.03 | 6.06 | – | – | – | – | – | – | – | – |
| 16 July | 24 | 56.00 | 24.00 | – | 8.00 | – | – | 8.00 | – | – | – | – | – | – | – | – |
| 17 July | 181 | 70.17 | 13.26 | 6.08 | 6.63 | – | 1.66 | 1.10 | 0.55 | – | – | – | – | – | – | 0.55 |
| 24 July | 23 | 26.09 | 43.48 | 21.74 | 4.35 | 4.35 | – | – | – | – | – | – | – | – | – | – |
| 30 July | 65 | 44.62 | 16.92 | 18.46 | 6.15 | 4.62 | 3.08 | – | 1.54 | – | – | – | – | 1.54 | – | – |
| 31 July | 125 | 55.20 | 12.80 | 9.60 | 11.20 | 3.20 | 5.60 | – | 1.60 | – | 0.60 | – | – | – | – | 0.80 |
| 7 Aug | 159 | 25.30 | 43.98 | 13.86 | 6.63 | 1.20 | 2.41 | – | 3.01 | – | – | – | 0.63 | – | 0.63 | 3.01 |
| 5 Sep | 128 | 43.94 | 17.42 | 28.03 | 5.30 | 0.76 | 0.76 | 0.76 | – | – | – | – | – | – | – | 0.76 |
| Average | | 43.67 | 24.25 | 8.59 | 10.90 | 1.97 | 2.51 | 0.90 | 0.52 | 0.11 | 0.05 | 0.28 | 0.05 | 1.10 | 1.00 | 0.89 |

Table 3. Dry weights (percentages) of different insect taxa in 13 1-hr samples.

| Date | Diptera | Formicidae | Other Hymenoptera | Hemiptera-Homoptera | Coleoptera | Collembola | Orthoptera | Thysanura | Isoptera | Lepidoptera | Dermaptera | Protura | larvae | unidentified | Arachnida |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1982 | | | | | | | | | | | | | | | |
| 2 May | 13.4 | 13.7 | 8.5 | 0.4 | 62.4 | – | – | – | 1.5 | – | – | – | – | – | – |
| 18 July | 81.0 | 7.5 | 0.9 | 6.1 | – | – | – | – | – | – | – | – | – | – | 4.5 |
| 1983 | | | | | | | | | | | | | | | |
| 2 July | 16.9 | 39.3 | – | 13.3 | – | 5.0 | – | – | – | – | 22.7 | – | 2.8 | – | – |
| 4 July | 31.8 | 17.3 | 2.1 | 15.8 | – | 19.0 | 7.4 | – | – | – | – | – | 1.8 | 4.9 | – |
| 10 July | 48.2 | 17.5 | 1.9 | 9.6 | 12.2 | – | – | – | – | – | – | – | – | 7.0 | 3.6 |
| 11 July | 47.8 | 9.7 | 1.6 | 11.5 | 14.3 | 11.6 | – | – | – | – | – | – | – | – | 3.4 |
| 16 July | 32.2 | 14.5 | – | 26.1 | – | – | 27.1 | – | – | – | – | – | – | – | – |
| 17 July | 79.1 | 8.5 | 8.4 | 2.2 | – | 0.4 | 0.2 | 0.1 | – | – | – | – | – | – | 1.0 |
| 24 July | 39.7 | 28.4 | 10.5 | 3.1 | 18.3 | – | – | – | – | – | – | – | – | – | – |
| 30 July | 34.0 | 11.8 | 10.5 | 5.0 | 23.3 | 5.8 | – | 2.9 | – | – | – | – | 0.6 | – | – |
| 31 July | 40.8 | 7.2 | 10.5 | 9.8 | 20.5 | 7.0 | – | 3.0 | – | 0.4 | – | – | – | – | 0.9 |
| 7 Aug | 10.8 | 12.3 | 6.5 | 5.8 | 34.8 | 5.7 | – | 9.0 | – | – | – | 2.2 | – | – | 9.5 |
| 5 Sep | 35.7 | 21.8 | 35.5 | 2.7 | 1.6 | 0.6 | 1.5 | – | – | – | – | – | – | – | 0.5 |

waters may be significant and is sometimes of major importance. Mating flights of ants and termites may result in immense swarms, many of which may fall into lakes and ponds or even into marine waters. In September 1983 I observed windrows of male and female carpenter ants (*Camponotus* sp.) washed up on shore at Dewey Beach, Delaware. These windrows extended south for at least 6 miles, to the Indian River inlet, and probably farther. Using a conservative estimate of 100 ants/inch of beach, about 38 million ants perished along this 6 mile stretch of beach.

Feeding on fallen terrestrial insects by fishes, especially trout, is well known. Insects on the surfaces of ponds and streams are also eaten by a number of aquatic Hemiptera in the families Gerridae, Veliidae, Notonectidae, and Belostomatidae (Cooper, 1984). Around the Galapagos Islands the marine water strider *Halobates robustus* feeds almost exclusively on terrestrial insects that have fallen onto the sea surface. (Foster and Treherne, 1980).

Use of a swimming pool has several advantages over a natural pond. The surface area is accurately known; there are no predators to remove the insects and decrease the numbers counted; there is no emergent vegetation to conceal the fallen insects; the surface area is large enough to give quantitatively significant numbers of insects and small enough to permit easy sampling.

It has been suggested that insects flying over the pool are stunned by aerial chlorine fumes that cause them to fall into the pool. However, chlorine added to the pool is in the form of a stabilized organic compound that releases chlorine very gradually; hence the possibility that the air above the pool becomes toxic to flying insects is remote.

## ACKNOWLEDGMENTS

I am grateful to Gerald A. Cole for advice and encouragement and for reviewing the manuscript, and to Paul Spangler for reviewing the manuscript.

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